Chapter 3

# Watershed Protection and *Smart* Site Design Requirements



## What's in this Chapter?

Section 3.1 discusses the elements of a "Smart site design" approach and defines terminology that is used throughout the remainder of this manual.

Section 3.2 describes the process of integrated stormwater management at different scales in which stormwater runoff is avoided, minimized, and managed from downspout to river mouth.

Section 3.3 discusses site inventory and assessment protocols and checklists as well as descriptions of special management areas with characteristics and/or limitations that affect the manner in which stormwater strategies may be implemented on a site.

Section 3.4 reviews the usage of smart site design techniques.

## 3.1 Elements of *Smart* Site Design

### 3.1.1 Terminology Related to Stormwater Control Measures in this Manual

Stormwater management is accomplished through a process that includes an integrated approach with a combination of structural and nonstructural strategies which can be explained by the following common terms:

- **Stormwater Management:** any action taken to minimize and mitigate the negative impacts of hydrologic modification and pollutant additions associated with stormwater infrastructure. This includes physical devices and techniques, but also more general strategies like minimizing fertilizer and pesticide use, reducing illicit discharges to drains, etc. Note that management will often take place between storm events through preventative approaches, though the purpose is to minimize contaminant availability and hydrologic impact during those events.
- **Stormwater Control Measures (SCMs):** are *Measures* meant to directly affect the discharge of stormwater and/or contaminants, and that have defined specifications and standards. These *Measures* have one or both of two parts: 1) a defined surface *Management* to encourage infiltration and/or pollutant removal; 2) a clear *Protocol* defining the engineering design, installation, and maintenance. A *Measure* such as a "good forest" (a forested area in good condition) has just a *Management*, a *Measure* such as a manufactured stormwater treatment device has just an engineering *Protocol*, and a "bioretention cell" has both.
- **Management:** a clearly defined state of soil and vegetation that provides the desired degree of infiltration and/or pollutant removal under the design conditions. This design condition is considered to be 15 years following stabilization, when the site has reached a reasonable level of maturity and is undergoing only gradual changes. The *Management* is the desired endpoint and depends on a series of *Techniques* to get from the current condition to that endpoint. A *Management* has clearly defined specifications in this manual, including vegetation type and density, soil hydrologic characteristics, etc. The term *Cover* is sometimes used to describe a *Management* that has minimal inputs.

- **Technique:** method or operation that progresses or sustains progress from one state of management to another higher-functioning management. These can fall in either of two general categories:
  1) Methods of getting from "here" to "there"; from the presumed worst-case condition immediately following development to the desired *Management* endpoint. The *Techniques* used in a specific site design will vary greatly depending on these starting conditions. For example, if an area of "good forest" is left undisturbed, no *Technique* at all is necessary to achieve a "good forest" *Management*. On the other hand, if the post-construction condition is a highly-disturbed mixture of soil layers and is heavily compacted, the required *Techniques* to achieve a "good forest" *Management* in 15 years might include the following: soil ripping; soil amendments; temporary vegetative cover; slope erosion control to allow establishment of the temporary vegetation; planting of trees of a specified type, size, and density; and perhaps fertilization and irrigation schedules or other maintenance requirements.
  2) The operations necessary to maintain the required trajectory towards the desired design condition and to maintain that condition once it is achieved. In other words, the *Protocol* for maintenance of a "good forest" *Management* might refer to *Techniques* for tree thinning, tree fertilization, and invasive species removal. Note that the Protocol for a "fair forest" *Management* might refer to the same *Techniques*, but with less intensive requirements.

**Figure 3.1: Stormwater management approach of storm drain stenciling, which identifies drains that discharge to local streams and states a no dumping regulation.**

### 3.1.2 Design Goals and Approaches

Successful permanent stormwater management programs and plans integrate effective management early on in the planning process, prevent rather than mitigate stormwater impacts, conserve site resources, and develop site designs with the terrain in mind. In the following sections of this chapter, we introduce ***Smart*** site design as a process to achieve watershed protection elements in new development, maximize use of site resources for stormwater management, and minimize the total treatment volume required for structural practices.

The goal of ***Smart*** site design is to plan how to generally reduce runoff volume while minimizing changes to pre-development hydrologic functions and to mitigate other environmental impacts as close to the impact as possible. The benefits of ***Smart*** site design are most apparent when incorporated into the site planning process as early as possible. This typically requires that certain considerations and allowances are made in the project concept phase. When applied early, the ***Smart*** site design approach can sharply reduce stormwater runoff and pollutants generated by development. This can reduce both the size and cost of stormwater infrastructure.

The ***Smart*** site design techniques described in this chapter are proactive management practices that minimize treatment volumes and the need for structural practices as well as enhance the longevity of a hydrologically-functional project site.

***Smart* site design objectives include:**

- Avoiding the generation of stormwater runoff during small storms;
- Managing stormwater (quantity and quality) as close to the point of origin as practically possible and minimizing the use of large or regional-scale collection and conveyance systems;
- Preserving natural areas, topography, vegetation, and soils to reduce overall impact on watershed hydrology;
- Using nonstructural methods for stormwater management that are lower in cost and have lower maintenance needs than structural controls;
- Creating multifunctional landscapes; and
- Using natural drainage pathways and the site's existing hydrologic processes as a framework for site design.

**Actions that can be taken to reach objectives:**

- Shrinking cleared/disturbed land area and impervious surface footprints
- Increasing travel distances of concentrated runoff
- Maximizing sheet flow and vegetated areas
- Minimizing site and lot slopes
- Use open conveyances with undisturbed soil bottoms.

There are three guiding principles that help achieve a ***Smart*** site design. These guiding principles will ensure that the required runoff treatment volume (and cost) is as low as possible under given site conditions and project considerations. The guiding principles are as follows:

1. ***Avoid*** generating stormwater runoff all together by preserving natural features.
2. ***Minimize*** impacts of land disturbance and total impervious surfaces.
3. ***Manage*** stormwater runoff with appropriate SCMs.

***Avoid:*** In the project concept phase, there are many actions that may be taken to preserve or improve a site's capacity to absorb rainfall and minimize runoff – or as defined within, the landscape capacity for infiltration. These include preserving undisturbed natural areas, preserving riparian buffers, preserving or planting trees, avoiding development in floodplains, avoiding steep slopes, and minimizing disturbance on soils that are relatively more erodible.

Headwater streams are unique and important features of a watershed. Researchers and water resource professionals recommend that stormwater managers pay specific attention to headwater streams in conservation and protection elements of their programs. While riparian buffers are requirements of site development plans and municipal stormwater permits, conservation of these areas minimizes the need for structural management practices. Riparian buffers and protected natural areas do not contribute runoff volume in the overall site mass balance approach to SCM design. This may be accomplished by a combination of the following approaches: preserve natural topography within project layout, use natural drainage flowpaths and vegetated swales instead of storm pipes and curb and gutter, direct runoff to pervious areas, preserve landscape capacity for infiltration by minimizing the extent of grading, and create small areas of depressional storage in infiltratable soils.

***Minimize:*** Reducing impervious surface coverage reduces the need for structural SCMs. Where appropriate, the following actions will reduce the volume of runoff for management in stormwater control measures: 1) reduce roadway lengths and widths, 2) reduce building footprints, 3) reduce parking area footprints, 4) use fewer or alternative cul-de-sacs, 5) fit layout to the terrain, 6) reduce the limits of clearing and grading, and 7) utilize open space development.

***Manage:*** Once all efforts are taken to avoid and minimize stormwater generation, there will be the need to implement structural SCMs to collect, manage, infiltrate, treat, or reuse runoff onsite or in offsite mitigation projects. Where possible, SCMs can be located within other elements of site design, such as setbacks and landscaping requirements. A suggested list of stormwater control practices including design specifications can be found in Chapter 5 of this manual. Check with the MS4 operator for a list of locally-approved SCMs.

## 3.2 Watershed Protection – From Downspout to River Mouth

### 3.2.1 Stormwater Management at Multiple Scales

Development patterns, community design, population density, and water availability have been linked throughout the course of history. These development factors significantly affect how communities function in terms of water use and quality. Managing critical water and land resources through ***Smart*** site design can reveal multiple benefits to communities related to economic prosperity and good quality of life experiences for citizens. Water resource management is done using the watershed as the operational unit. We now know that using a watershed approach to development is also crucial for the sustainable growth of our communities.

The greatest benefit of implementing permanent stormwater management and smart site design will be seen at the watershed scale in the improved quality and function of our rivers and streams. By utilizing practices on multiple spatial scales (single lot, streetscape, neighborhood, city) to mimic natural hydrologic functions at the watershed level, we will experience healthier streams and rivers in our communities. Community planning actions at the watershed-scale that will work to achieve this include:

1. **Compact and Mixed-Use Development** – Using small lots, higher densities, and a connected street system, compact designs are a strategy for reducing development footprints of city centers. Mixed-use development also decreases footprints by increasing transportation options and minimizing the need for wide/large freeways.
2. **Street Networks** – Creating a network of well-connected streets enhances traffic circulation while decreasing road footprints.
3. **Infill and Redevelopment** – Reusing existing impervious surfaces and existing infrastructure minimizes the generation of additional stormwater runoff.
4. **Stormwater Management Retrofits** – Investing in replacing gray infrastructure with green infrastructure decreases the impact on streams and rivers that receive urban runoff from existing developments.
5. **Open Space Development** – Clustering houses into one area and preserving open space minimizes land disturbance, protects native soils and vegetation, and creates opportunity for disconnection practices.

The fundamental difference between conventional and ***Smart*** site design development is the way in which a project is initially conceived. A conventional development typically deals with runoff as something to move away from the project site as quickly as possible. A ***Smart*** site design development project is conceived with rainfall and runoff management in mind throughout the planning phase, by placing value on the natural landscape capacity to absorb rainfall and preserving these elements of a site. When runoff is generated in excess of the landscape capacity for infiltration, then that runoff is managed as close to its source as possible. Implementing the following principles in the concept phase of project development will ensure that the minimal amount of stormwater runoff is generated, therefore minimizing the size and extent of structural practices.

From the watershed scale to lot scale, the elements of ***Smart*** site design may be implemented in different applications to guide community development, neighborhood design, and individual parcel layout. The following tables discuss the movement of stormwater from rainfall, through a watershed, and into receiving surface waters, and document how management practices can be changed to achieve a watershed approach. Table 3.1 examines applications in a residential setting; Table 3.2 in a commercial or industrial setting.

**Table 3.1: From Rooftop to Stream: Stormwater Management in a Residential Setting (Adapted from NRC 2009).**

| Approach | What it is | What it replaced | How it works |
|---|---|---|---|
| Site Planning | Early site assessment | Performing stormwater management design after site layout | Map and design plan submitted at earliest stage of project development review showing environmental, drainage, and soil features |
| Conservation of Natural Areas | Maximize forest canopy, green space | Mass clearing | Preservation of priority forests and meadow and reforestation of turf areas to intercept rainfall |
| Earthwork Minimization | Conserve soils with good infiltration as well as existing contours | Mass grading and soil compaction | Construction practices to conserve soil structure and minimize the compacted footprint |
| Impervious Cover Minimization | Smart site design | Large streets, lots and cul-de-sacs | Narrower streets, permeable driveways, clustering lots, and other actions to reduce pavement |
| Runoff Reduction – Impervious Surface Disconnection and Rainwater Harvesting | Using rooftop runoff | Directly connected roof gutters | A series of practices to capture, disconnect, store, infiltrate, or harvest rooftop runoff |
| Runoff Reduction – Infiltration and Filtration | Front yard bioretention and vegetated swales | Drainage from roof to roadway; curb/gutter and storm drain pipes | Grading to treat roof, lawn, driveway, and roadway runoff using vegetated depressional storage and conveyance |
| Peak Reduction and Treatment | Strategic use of SCMs | Large detention ponds | Multiple SCMs that have sufficient storage volume and are distributed on site may be designed to provide some amount of peak reduction |
| Aquatic Buffers and Managed Floodplains | Stream buffer management | Unmanaged stream buffers (building or mowing up to the stream bank) | Active revegetation of buffers and restoration of degraded stream channels |

**Table 3.2: From Rooftop to Stream: Stormwater Management in a Commercial or Industrial Setting.**

| Approach | What it is | What it replaced | How it works |
|---|---|---|---|
| Pollution Prevention | Drainage mapping | No map | Analysis of the locations and connections of the stormwater infrastructure from the site |
| | Hotspot site investigation | Visual inspection | Systematic assessment of runoff problems and pollution prevention opportunities at the site |
| | Rooftop management | Uncontrolled rooftop runoff | Use of alternative roof surfaces or coatings to reduce metal runoff, and disconnection of roof runoff for stormwater treatment |
| | Exterior maintenance practices | Traditional practices | Special practices to reduce discharges during painting, powerwashing, cleaning, sealcoating, and sandblasting |
| | Extending roofs for no exposure | Exposed hotspot operations | Extending covers over susceptible loading/unloading, fueling, outdoor storage, and waste management operations so pollutant sources are not exposed to rainfall |
| | Vehicular pollution prevention | Uncontrolled vehicle operations | Pollution prevention practices applied to vehicle repair, washing, fueling, and parking operations |
| | Outdoor pollution prevention practices | Outdoor materials storage | Prevent rainwater from contacting potential pollutants by covering, providing secondary containment, or diverting from storm drains |
| | Waste management practices | Exposed dumpster or waste streams | Improved dumpster location, management, and treatment to prevent contact with rainwater or runoff |
| | Spill prevention control and response plans | No plan | Develop and test response to spills to the storm drain system, train employees, and have spill control kits available on site |
| | Greenscaping | Routine landscape and turf maintenance | Reduce use of pesticides, fertilizers, and irrigation in pervious areas, and conversion of turf to forest or bioretention |
| | Employee stewardship | Lack of stormwater awareness | Ongoing training of employees on stormwater problems and pollution prevention practices |
| | Site housekeeping and stormwater maintenance | Dirty site and unmaintained infrastructure | Regular street sweeping of roads and parking areas, storm drain cleanouts, litter pickup, and maintenance of stormwater infrastructure |
| Runoff Treatment | Stormwater Retrofitting | No stormwater treatment | Installing SCMs to remove pollutants from existing hotspot areas |
| Illicit Discharge Detection and Elimination | Outfall monitoring and analysis | Intentional and unintentional discharges of pollutants | Observing and monitoring of outfalls to measure effectiveness |

### 3.2.1.1 Watershed Scale

Approaches to avoid and minimize stormwater runoff are often design decisions that reduce impervious surface footprints or that will convey stormwater through the site with SCMs that promote infiltration and evapotranspiration. These design decisions are best implemented during the concept and initial development phase of a project. If these approaches are implemented correctly, then overall stormwater management costs will be minimized for a project. This section focuses on ways to reduce impervious areas, while other sections of this manual describe SCMs that can be used to reduce the stormwater volume.

Alternative and/or vertical (taller) building designs should be considered to reduce impervious rooftop area. Consolidate functions and buildings or segment facilities to reduce the footprint of individual structures. Figure 3.2 shows the reduction in impervious footprint by using a taller building design (RIDEM, 2011).

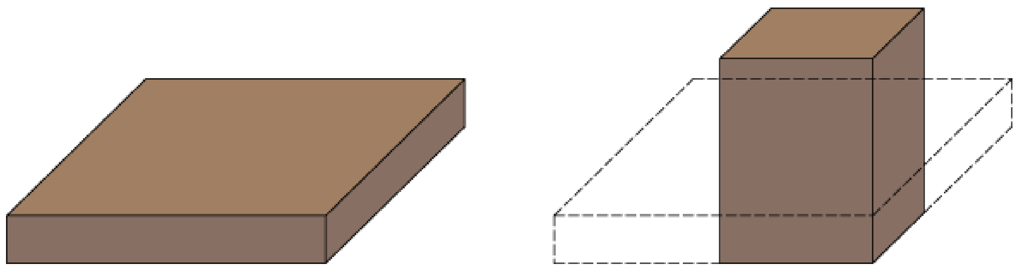


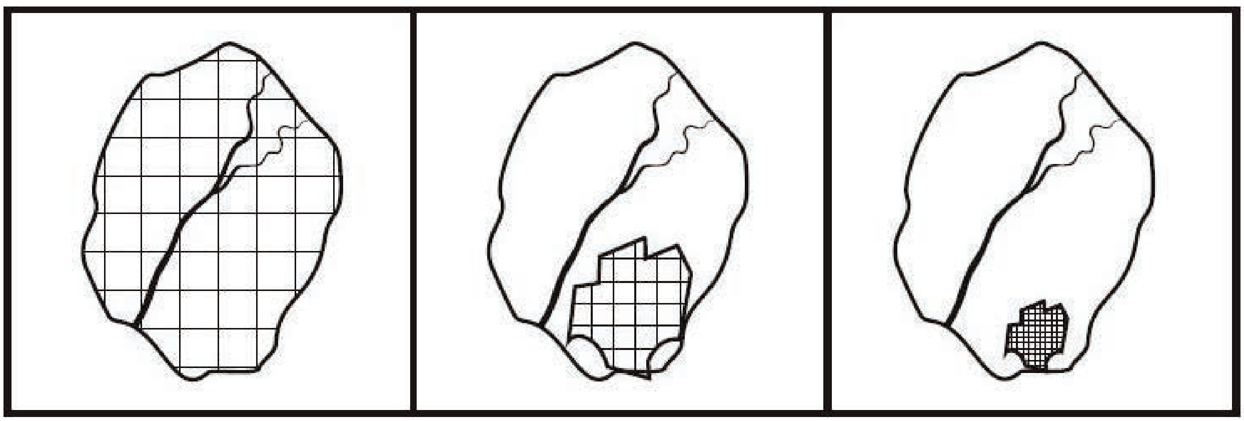

**Figure 3.2: Representation of how a vertical design decreases the total amount of impervious surface created.**

Higher housing densities may also better protect water quality, especially at the watershed scale. According to the American Housing Survey, 35% of new housing is built on lots between two and five acres, and the median lot size is just below one-half acre (US Census, 2001). Local zoning may encourage building on relatively large lots, in part because local governments often believe that it helps protect their water quality (US EPA, 2006). Communities have assumed that low-density development at the site level results in better water quality. Such conclusions are often drawn from analysis that assumes a one-acre site has one or two homes with a driveway and a road passing by the property and the remainder of the site is well-established lawn. However, this logic overlooks two key caveats: first, that the “pervious” surface remaining in low-density development is in fact additional land disturbance and might create a hydrologic response that looks more similar to impervious surface than predevelopment forests, and that secondly, low-density developments often require more off-site impervious infrastructure for utilities, transportation, and safety (US EPA, 2006).

In the experimental scenario below (Figure 3.3), the US EPA used commonly accepted hydrologic models to examine the question of which type of development (high density or low density) better protects overall watershed function. At the watershed scale, there is less overall runoff generated from a high-density development than a low-density development due to the fact that there is more preserved undisturbed areas in the high-density development, which will naturally absorb much of the frequent small storm precipitation.


| Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|
| *Impervious cover* = **20%** | *Impervious cover* = **38%** | *Impervious cover* = **65%** |
| *Runoff/acre* = **18,700 ft$^3$/yr** | *Runoff/acre* = **24,800 ft$^3$/yr** | *Runoff/acre* = **39,600 ft$^3$/yr** |
| *Runoff/unit* = **18,700 ft$^3$/yr** | *Runoff/unit* = **6,200 ft$^3$/yr** | *Runoff/unit* = **4,950 ft$^3$/yr** |

**Figure 3.3: Total average annual stormwater runoff for all scenarios (US EPA, 2006).**



| | | |
|---|---|---|
| **10,000 houses** *built on* **10,000 acres** *produce:* | **10,000 houses** *built on* **2,500 acres** *produce:* | **10,000 houses** *built on* **1,250 acres** *produce:* |
| 10,000 acres x 1 house/acre x 18,700 ft$^3$/yr of runoff = | 2,500 acres x 4 houses/acre x 6,200 ft$^3$/yr of runoff = | 1,250 acres x 8 houses/acre x 4,950 ft$^3$/yr of runoff = |
| **187 million ft$^3$/yr of stormwater runoff** | **62 million ft$^3$/yr of stormwater runoff** | **49.5 million ft$^3$/yr of stormwater runoff** |
| ***Site:*** *20% impervious cover* | ***Site:*** 38% impervious cover | ***Site:*** 65% impervious cover |
| ***Watershed:*** *20% impervious cover* | ***Watershed:*** 9.5% impervious cover | ***Watershed:*** 8.1% impervious cover |

**Figure 3.4: 10,000-acre watershed accommodating 10,000 houses (US EPA, 2006).**

### 3.2.1.2 Project Site Scale

Mixed-use development can also reduce parking lot footprint with shared parking. Shared parking can be defined as parking utilized jointly among different buildings and facilities in a single area to take advantage of different peak parking characteristics that vary by time of day or day of the week. Since most parking spaces are only used part time, shared parking arrangements are designed to more efficiently meet the needs of areas that exhibit a mix of uses with varying peak parking demands. For example, many businesses or government offices experience their peak business hours during the daytime on weekdays, while restaurants peak in the evening hours and on weekends. This presents an opportunity for shared parking arrangements where several different groups can use an individual parking lot without creating conflicts (RIDEM, 2011).

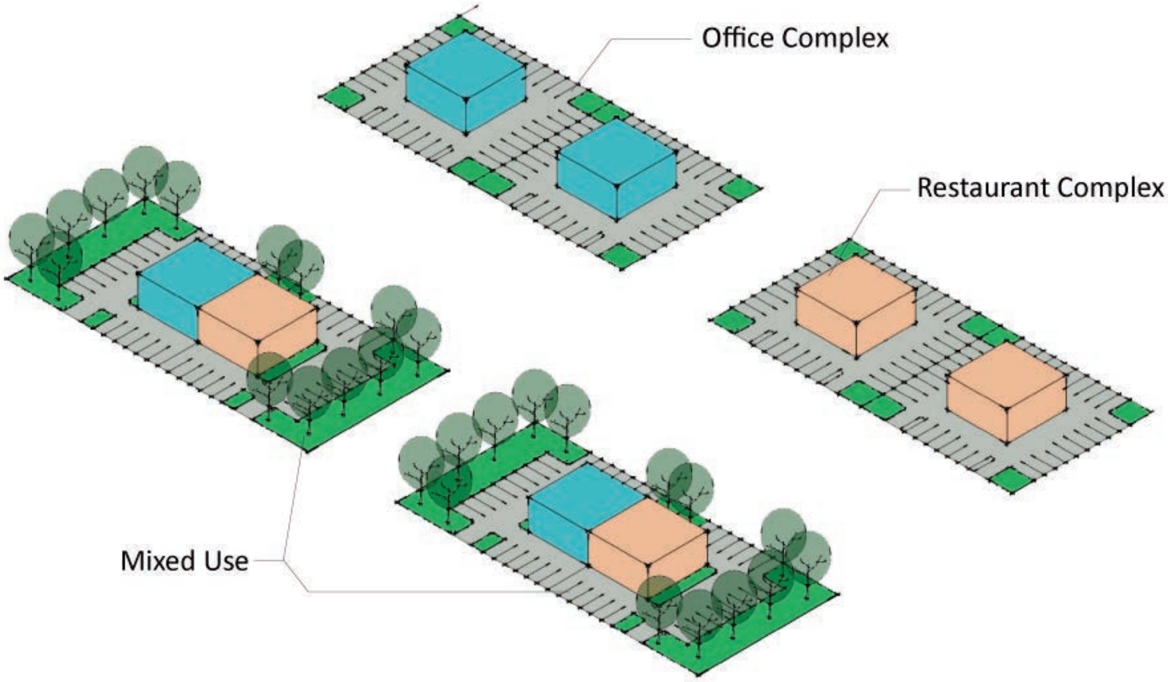



**Figure 3.5: Example of separate complex development and mixed-use development.**

Mixed-use development is not a new planning concept. Many of the region's older downtowns and neighborhood centers have homes, shops, offices, and schools built closer together and connected by a fine grid of streets that allow people to walk, bike or take transit in order to meet their daily needs. This approach not only replicates the pedestrian-friendly character of the older parts of the cities, but also benefits water quality by reducing the overall amount of impervious surface dedicated to streets and parking lots (US EPA, 2009).

Residential road layout generally falls into three categories: grid, curvilinear, and hybrids. As illustrated in the figure and table below, grid and curvilinear layouts have practical benefits, and hybrid designs attempt to take the best features of the two (Hinman, 2005).

**Table 3.3: Description of residential road layout.**

| Road pattern | Impervious coverage | Site disturbance | Vehicle Efficiency | Biking, Walking, Transit |
|---|---|---|---|---|
| Grid | 27-36% | Less adaptive to site features and topography | More efficient – disperses traffic through multiple access points | Promotes by more direct access to services and transit |
| Curvilinear | 15-29% | More adaptive for avoiding natural features, and reducing cut and fill | Less efficient – concentrates traffic through fewer access points and intersections | Generally discourages with longer, more confusing, and less connected system |


**Figure 3.6: From left to right: grid, curvilinear, and hybrid pattern (AHBL, 2002).**

Streets offer unique opportunities for handling and treating their runoff, but conventional street design practices focus primarily on moving the automobile and diverting runoff to the curb and gutter, contributing to increased runoff volume and poor water quality (US EPA, 2009). Residential streets and private streets within commercial and other development should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency access. Many communities require minimum street widths that are much wider than needed to support travel lanes, on-street parking, and emergency access. Access streets in subdivisions often are wider than the collector and higher order streets that receive their traffic. Ironically, excessively wide streets also encourage excessive vehicle speeds (RIDEM, 2011). Narrower streets can be used in most residential development that generate less than 500 average daily trips (ADT), perhaps widths of 22–26 feet (Cook, 2007). Narrower streets could also be feasible for streets with 500–1,000 ADT (US EPA, 2014).

Road length also is an important issue. Road length should first be addressed from a macro-level planning perspective. Overall higher density patterns of development result in less road construction than low density patterns, if the net amount of development does not increase. High-density development and vertical development contrast sharply with low density sprawl, which has proliferated in recent years and has required vast new highway systems throughout urban fringe zones (RIDEM, 2011).

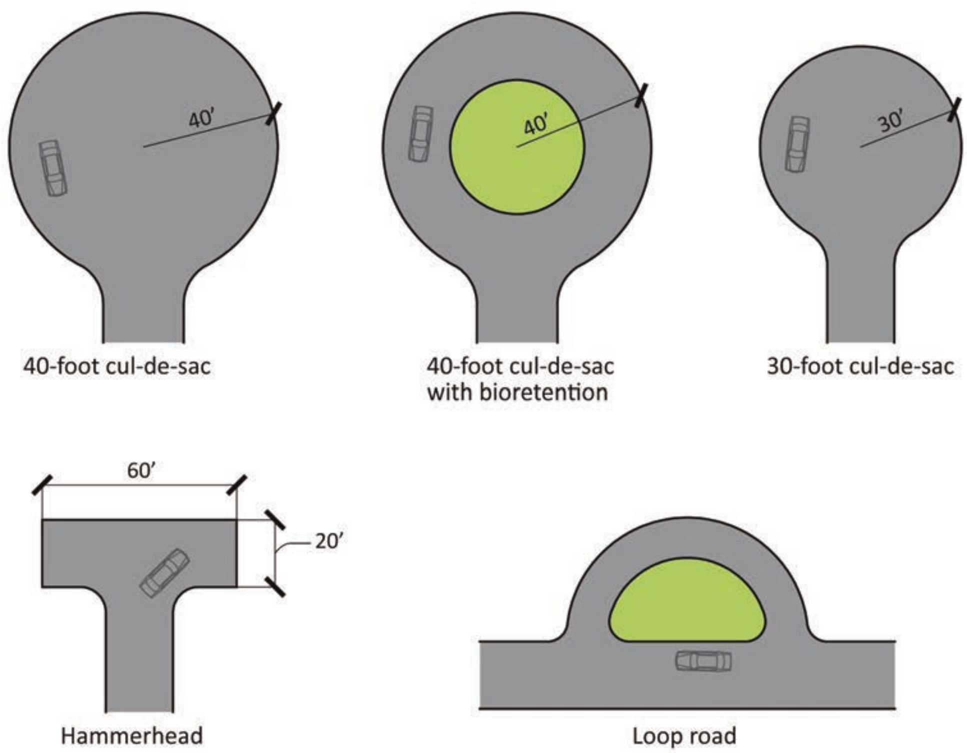



**Figure 3.7: Various road designs. (adapted from Schueler, 1995).**

Parking lots, like streets, make up large areas of impervious surface and contribute to polluted runoff. To minimize the total impervious area, set appropriate parking ratios for development projects and allow businesses to count underused nearby on-street parking spaces toward meeting their parking requirements.

Cul-de-sacs can also increase impervious area. In general, cul-de-sacs should be discouraged; however, a number of alternatives are available where conducive with topography, soils, or other site-specific conditions that create less impervious cover than the traditional 40-foot cul-de-sac (Fig. 3.7). These alternatives include reducing cul-de-sacs to a 30-foot radius, creating a hammerhead tee, or creating a loop. Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and many school buses usually do not enter individual cul-de-sacs (RIDEM, 2011).

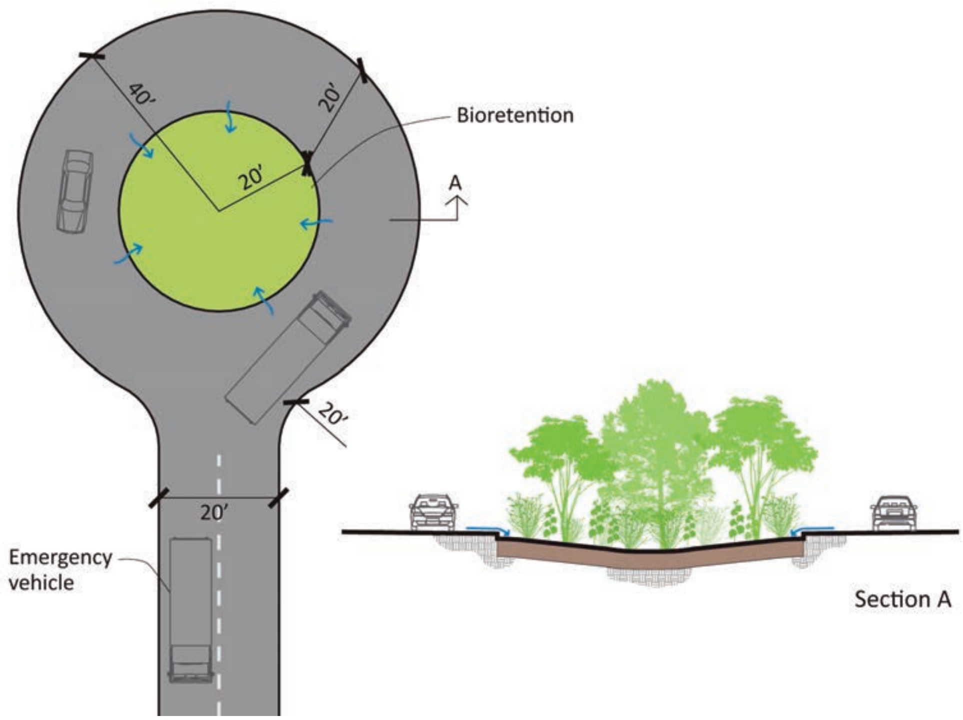



**Figure 3.8: Cul-de-sac with bioretention.**

Right-of-ways (ROWs) are pieces of land reserved for transportation, utilities and other uses. One inch of rain falling on one block of a typical city street (40’ x 300’) generates some 6700 gallons of stormwater runoff. This runoff can become a problem for communities in the form of downstream flooding and non-point source pollution or it can become a resource providing moisture for neighborhood vegetation if captured close to the source. Many ROWs are un-vegetated, featuring only earthen areas of compacted dirt or uniform gravel. These areas can be used to infiltrate stormwater from neighborhood streets. ROWs are legally and logistically easier to work in than the street itself, making them good locations for volunteer-led neighborhood tree-planting efforts and green infrastructure projects (McAdam, 2010).


**Figure 3.9: A low-density street in Knoxville, TN (Source: SMART Center).**

**Figure 3.10: Conceptual representation of the same street retrofitted with linear bioretention, a bike lane, and street trees (Source: SMART Center).**

Eliminating curbs and gutters on streets will typically require installation of vegetated swales to accept the stormwater runoff from the street. Traditional curbs and gutters are very effective at quickly collecting and delivering stormwater runoff to a central location. As a result, they provide limited opportunity for the removal of pollutants. Elimination of curbs and gutters and the introduction of vegetated swales, bioretention and filter strips to collect and convey runoff are suitable for a range of conditions. Where adequate space exists and traffic conditions will allow, this approach will allow for filtering, infiltration, and reduction of peak runoff volumes and flow velocity (Cook, 2007).

### 3.2.1.3 Lot Scale

Structural SCMs can also be used in conjunction with the previously mentioned nonstructural approaches to avoid and minimize the generation of stormwater. SCM design specifications and implementation information can be found in Chapter 5. These practices are designed to capture or treat a specific volume of runoff from the impervious surfaces of a residential or commercial site and can be integrated into a larger site plan.

Lot scale stormwater management is greatly effective because it manages stormwater runoff close to the point of origin. Using a system of small, diffuse structural measures to meet design targets is generally less demanding with regards to the level of complexity in engineering design and needed physical materials. However, this approach requires coordination with property owners and their involvement in the maintenance of structural measures to ensure they are functioning as designed.

**Figure 3.11: Photographs of lot scale runoff reduction measures. Left: a roadside vegetated verge (without curb or gutter) that accepts roadway runoff, uses engineered soils to infiltrate runoff, and conveys excess runoff to a small treatment wetland. Right: a residential rain garden captures and infiltrates runoff from the house rooftop and driveway.**

### 3.2.2 The Role of Redevelopment

Redevelopment is defined as new construction on a site that has pre-existing uses. Redevelopment projects also present new opportunities for stormwater management (Table 3.4). Promoting infill development and redevelopment is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, redevelopment is more complex because of the need to upgrade existing infrastructure, the limited availability and affordability of land, and the complications caused by rezoning. These sites might also require cleanup or remediation before redevelopment can occur (see section 3.3.2 for special management areas). Innovative incentives along with careful selection of SCMs can be used to achieve effective stormwater management systems in these areas.

**Table 3.4: From Rooftop to Stream: Stormwater Management in Redevelopment Projects.**

| Approach | What it is | What it replaced | How it works |
|---|---|---|---|
| ***Smart*** Site Design | Site design to prevent pollution through minimizing impervious cover | Conventional site design | Designing the redevelopment footprint to restore natural area remnants, minimize impervious cover, and reduce hotspot potential |
| Runoff Volume Reduction – Disconnection and Rainwater Harvesting | Rooftop treatment on the roof or in the landscaping | Traditional rooftops and directly connected downspouts | Use green roofs to reduce runoff generation; Use rain tanks to capture and reuse rainfall; Use rain gardens to capture and infiltrate parking lot and rooftop runoff. |
| Soil Conservation and Reforestation | Runoff reduction in pervious areas and increased tree canopy | Impervious or compacted soils and turf grass | Reduce runoff from compacted soils through tilling and compost amendments; Providing adequate rooting depth for mature tree development. |
| Runoff Reduction – Subsurface | Increase permeability of impervious cover | Impermeable asphalt or concrete | Use of permeable pavements to decrease runoff and increase infiltration. |
| Runoff Reduction – Vegetated | Runoff treatment in the street | Sidewalks, curb and gutter, and storm drains | Use bioretention planter boxes to capture, filter, and/or infiltrate runoff. |

*continued on next page*

**Table 3.4 – continued**

| Approach | What it is | What it replaced | How it works |
|---|---|---|---|
| Runoff Treatment | Filtration for water pollutants | Catch basins and storm drain pipes | Use underground sand filters or other devices to treat hotspot runoff. |
| Municipal Good Housekeeping | Street cleaning | Unswept streets | Street cleaning on priority areas to remove trash, leaves, sediment, and solids. |
| Watershed Planning | Off-site stormwater treatment or mitigation | On-site waivers | Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met on-site. |

## 3.3 Site Inventory and Assessment

***Smart*** site design can only be fully attained with a complete and thorough initial site inventory, assessment of existing hydrologic function, and documentation of special management conditions. The section below outlines the components of a site inventory and assessment, and delineates special management areas based upon the presence of native and built conditions.

There are many conditions that affect the way water moves through a site. The pre-development infiltrative capacity of soils at the site, defined as a site's ***landscape capacity*** in this manual, should be taken into account when designing SCMs or determining permit requirements. ***Special management areas***, defined later in this chapter, must also be taken into account in order to ensure the protection of water quality and SCM function. Local stormwater programs may create provisions that allow development to occur under these special circumstances.

### 3.3.1 Protocols and Checklists

The intended use of a project site greatly affects the selection and performance of stormwater management approaches, the implementation of smart site design and the selection of stormwater control measures. Characteristics that delineate land use types are described in generalities below:

- **Rural:** Impervious surfaces are generally dispersed, a significant percentage of acreage is in managed turf, while some areas are especially suited for minimization and avoidance approaches as well as vegetated infiltration-based SCMs. This is generally the existing condition for a greenfield development project.
- **Residential:** Medium to high density residential developments (less than 1/3 acre lot size). The amount of open green space is generally limited relative to rural areas, and measures are likely to be proximate to homes and buildings, creating a greater need to address safety and maintenance considerations.
- **Roads and Highways:** Linear corridors that typically generate high stormwater pollutant loads due to vehicle traffic and road maintenance activities. Limitations on the use of SCMs are generally dependent on adequate space as well as the potential for additional design requirements for large storm conveyance.
- **Commercial:** Variable size and management of drainage areas, potential for large sub-basin drainage scale measures, and limitations due to site-specific characteristics and flowpath routing.
- **Industrial:** Variable size and management of drainage areas, high potential for hotspots, and limitations due to site-specific characteristics and flowpath routing.

The following table shows how specific SCMs are recommended or considered conditional for use within a project land use context (Table 3.5).

**Table 3.5: Stormwater Control Measure Recommendations Based on Project Land Use.**

| Stormwater Control Measure | Rural | Residential | Roads & Highways | Commercial | Industrial |
|---|---|---|---|---|---|
| Filter Strips[1] | preferred | preferred | preferred | preferred | limited[2] |
| Infiltration Areas | preferred | preferred | conditional[2] | limited[3] | conditional[2,3,5] |
| Bioretention | preferred | preferred | conditional[2] | limited[2] | conditional[2,5] |
| Permeable Pavement | limited[6] | limited[6] | limited[6] | preferred | conditional[2,5] |
| Vegetated Swales | preferred | preferred | preferred | limited[7] | limited[7] |
| Managed Vegetated Areas | preferred | preferred | preferred | preferred | preferred |
| Rainwater Harvesting | preferred[4] | preferred[4] | NA | conditional[4] | conditional[4] |
| Manufactured Filter Device | limited[9] | limited[9] | preferred* | preferred* | preferred[2] |
| Stormwater Wetlands | preferred[2*] | preferred[2*] | preferred[2*] | preferred[2*] | preferred[2*] |
| Green Roofs | limited[8] | limited[8] | NA | limited | limited |

* *Preferred method for water quality treatment where infiltration is not allowed.*
*Preferred – Most effective selection.*
*Limited – Likely not the best selection, but might be applicable. Might also have conditional use requirements.*
*Conditional – Might need granted approval from the local stormwater program.*

*1 Filter Strips include sheet flow to infiltration areas.*
*2 May require pretreatment depending on land use and pollutant loading.*
*3 Intended for residential or other small impervious surface areas.*
*4 Requires a designated activity to reuse the harvested water.*
*5 Depending on land use, might limit infiltration and require additional maintenance.*
*6 Due to maintenance requirements.*
*7 Due to drainage area and large storm conveyance.*
*8 Typical residential roof geometry restricts application.*
*9 Excessive maintenance burden of underground systems in residential areas.*

**Existing Hydrologic Function:** The first step in creating a conceptual development plan is to document existing site conditions that affect hydrologic functions and have an impact on the practicality and successful implementation of smart site design. Designers must identify any physical constraints at the project site that might restrict or preclude the use of particular SCMs, and they must determine the ***landscape capacity*** for infiltration of rainfall. The primary factors to assess are described in detail below. More detailed site investigations might be needed to adequately address some constraints and might be required by the local stormwater program.

1. **Soil Texture:** The most relevant soil information is the Hydrologic Soil Group classification, which can be found for most areas in the web soil survey at:

   http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

   Field core data can also be used to describe soil texture and color as well as any redoximorphic features. Soil hydraulic conductivity information might also be included in the web soil survey but should be verified through one of the suggested field tests (See Appendix A).
2. **Depth to Water Table:** Shallow water tables might lead to SCM failure or contamination of groundwater if certain practices are used. This information might be found in soil surveys and should be verified through field observations.
3. **Depth to Bedrock:** Shallow bedrock might limit the effectiveness of infiltration practices. The depth to bedrock can be obtained through the soil survey or determined through field observations.
4. **Topography:** The overall lay of the land dictates the flow of surface water and also influences groundwater. Topographic information for conceptual planning purposes can be found in online databases or surveyed in the field using surveyor's equipment for complete project design. Land slope governs the way water moves in overland flow and concentrated flow and has a large

influence on the infiltration capacity of a site. Slope can be determined using topographic maps but should also be verified through a site survey at the scale required for plan submission by the local stormwater program.

5. **Contributing Drainage:** This is the land area that drains to a point of interest. For structural SCMs, the contributing drainage area must be determined from the final grading plan in order to accurately design the system.

### 3.3.2 Special Management Areas

These areas possess a characteristic or condition that either limits the use of infiltration-based SCMs or influences the design of structural practices to accommodate for the condition. These limitations are divided into two general categories, natural conditions and built conditions. They are described below. These conditions limit the landscape capacity for infiltration and therefore affect the approach and design for SCMs. If these conditions exist on a site, then the design must account for them. Check with the local stormwater program for any needed approvals or special procedures.

1. **Natural Conditions:** Natural conditions that create special management areas are those that are characteristic to the physiographic region and limit the landscape's capacity to infiltrate stormwater runoff. Conditions of concern for SCM design are described below. Additional conditions might also be identified by the local stormwater program.

   a. **Karst geology** – a unique type of landscape that is formed by the dissolution of rocks, such as limestone and dolomite. Karst areas have a high potential to contain large preferential pathways in soil overburden that are directly connected with the groundwater. This is a concern regarding SCM design because increasing infiltration in a karst area might lead to structural failures in subsurface layers and above ground structures. See Appendix B for detailed guidance on SCM design in karst geology.

   b. **Steep Slopes/Erodible Soils** – a combination of steep topographic relief (greater than 25%) and non-colloidal soils that are easily erodible. This is a concern in SCM design because the preferred method for runoff reduction and pollutant removal is through infiltration, while the preferred method of development on sites containing steep slopes is to protect them from site disturbances and avoid increasing the amount of run-on to these areas. If this is not possible, the options for steep slopes include: 1) re-vegetate or use biotechnical stabilization practices, 2) divert water away from the steep slope to a lower elevation without causing erosion, and 3) use a combination of terracing and vegetative filter strips on the slope as a stormwater control measure.

   c. **High Water Table** – areas that have a seasonally high water table that exists within 4 feet of the soil surface. This limits the use of infiltration-based SCMs, but might indicate desirable conditions for stormwater wetlands. If this condition exists on only a portion of a project site, the remainder of the project site might be suitable for infiltration-based practices.

   d. **Shallow Soils** – soil profiles that measure less than 4 feet above bedrock or a confining soil layer. The presence of shallow soils on a site limits the effectiveness of infiltration-based stormwater control measures. If this condition exists on only a portion of a project site, the remainder of the project site might be suitable for infiltration-based practices.

   e. **Low Permeability Soils** – soils that have low infiltration rates and therefore cause rainfall to run off the surface at a relatively faster rate than soils with high infiltration rates. These soils have high clay content or might be the result of compaction. Amending or tilling the soil can improve infiltration.

   f. **Sensitive or Impaired Receiving Waters** – areas within the watershed boundaries of a sensitive or impaired waterway (designated by a state or local program) might have unique requirements for stormwater management that change the selection and design of SCMs. For a list of impaired waterways, access the State's 303(d) list at the Tennessee Department of Environment and Conservation's website:

   http://www.tn.gov/environment/article/wr-wq-water-quality-reports-publications

A GIS map is also available at:

http://tdeconline.tn.gov/dwr/

Check with your local municipal program for information on sensitive water resources and additional requirements.

2. **Built Conditions** – As with natural physical conditions, pre-existing built (or anthropogenic) conditions on a project site can also affect hydrologic functions and successful implementation of SCMs. These are described below:
   a. **Brownfield/Soil Contamination** – Contamination due to a pre-existing land use on the project site. These conditions generally need to be remediated to a level where SCMs and site development will not result in the transport of contaminants downstream or into groundwater.
   b. **Pollution Hotspots** – land use characteristics that pose a relatively higher potential to contribute to surface or groundwater pollution due to the nature of contaminants that are associated with the current operations or land use. Some examples of these are gasoline stations, trash collection areas, mulching operations, chemical storage facilities, car washes, and plant nurseries.
   c. **Groundwater Pollution Potential** – projects that contain land use characteristics that have the potential to contribute to groundwater pollution if infiltration is used on site.

## 3.4 Summary

As described in Chapter 2 of this manual, MS4 permits in Tennessee require a design for site development to meet specific performance standards for the management of the first inch of rainfall. The 2010 general permit included a combination of runoff reduction and pollutant removal standards, while the 2016 general permit focuses solely on pollutant removal. A permitted MS4 operator may use either set of standards as the basis for their local program. The first edition of this manual was issued in December 2014 and corresponds to the 2010 general permit. This second edition of the manual is a revision of the first edition and corresponds more closely to the 2016 general permit.

The various elements of ***Smart*** site design are useful ways to meet design criteria and may be applied in different ways at different sites, depending on landscape capacity and existing site conditions. The appropriate use of ***Smart*** site design should be determined through the site assessment process as well as during the pre-concept design meetings between the project manager/developer and the local stormwater program.

To conclude this chapter, the following list describes the basic elements of ***Smart*** site design.

1. **Minimize impervious surfaces** – Shrink the impervious footprint of sites by reducing the width of roads, replacing impervious surfaces with permeable alternatives, and/or optimizing street layouts.
2. **Preserve, protect, create, and restore ecologically sensitive areas** – During development stages, take actions to protect streams, wetlands, floodplains, karst features, and steep slopes.
3. **Prevent or reduce impacts to streams** – Establish and maintain riparian buffer vegetation and use practices that disconnect runoff from impervious surface conveyances and directs it onto permeable areas.
4. **Avoid or prevent hydromodification of streams and other waterbodies** – Minimize the number of stream crossings or other modifications to water resources to prevent water quality and resource degradation.
5. **Protect trees and other native vegetation** – Limit the clearing of native vegetation, integrate open green spaces where possible, and include provisions to protect existing trees and their root systems during the site development process.
6. **Protect native soils** – Avoid removing or compacting the topsoil layer, and use construction phasing to minimize the overall disturbance footprint.

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